
PROPULSION DIRECTORATE

Monthly Accomplishment Report December 2004



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MICROPROPULSION SYSTEM
LAUNCHED AS PART OF
UNIVERSITY PROJECT:

A micropropulsion system designed and developed by the Propulsion Directorate was launched into space on 21 December 2004. The Free Molecule Micro-Resistojet (FMMR) is a MicroElectroMechanical Systems (MEMS) fabricated thruster system capable of performing on orbit maneuvers for small spacecraft. The FMMR is part of a university project dubbed Three Corner Nanosatellite, which provided research satellites for integration on-board Boeing's Delta IV Heavy Lift Demo. This university project is a joint effort

between Arizona State University (ASU), the University of Colorado at Boulder, and New Mexico State University, and is part of a joint Air Force Space Command/AFRL/DARPA/NASA-Goddard Space Test Program. On this mission, the FMMR thruster was to perform several thermal tests of the MEMS fabricated heater chip, which is an integral part of the thruster system. Tests of the heater chips were to be performed to assess the MEMS fabricated components after launch, and initial tests were to include thermal cycling of the chip during time in sun and in eclipse. Unfortunately, the University Nanosatellites were released from the launch vehicle prematurely and never made it to orbit. However, a future flight will provide an evaluation of the entire propulsion system's performance during an orbital maneuver on an ASU nanosatellite mission, ASUSat III. (Dr. I. Wyszong, AFRL/PRSA, (661) 275-5206)



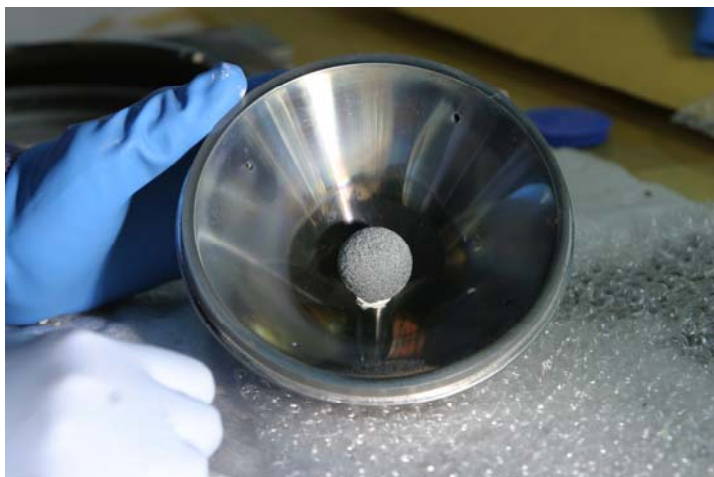
Two nanosatellites attached to the side of Boeing's Demo Sat, a satellite demonstrator for the inaugural flight of the Delta IV Heavy Launch Vehicle

FIRST VOLUMETRIC ABSORBER BASED SOLAR THERMAL THRUSTER TESTED: The Propulsion Directorate recently tested the first ever solar thermal thruster utilizing a volumetric



Solar thermal thruster shown mounted in the vacuum chamber

absorber at the AFRL Solar Laboratory at Edwards AFB, California. The design of the thruster was a joint effort between the Propulsion Directorate and SRS Technologies of Huntsville, Alabama. This test achieved a number of significant milestones. The absorber temperature exceeded that needed to meet Integrated High Payoff Rocket Propulsion Technology (IHPRPT) Solar Thermal Propulsion Phase I goals. The secondary concentrator survived several thermal cycles and several hours of testing with no degradation, and the window also survived several hours of



The solar thermal thruster's secondary concentrator and absorber

high intensity sunlight and thermal radiation from the absorber with no degradation. Furthermore, the porous molybdenum absorber operated at temperatures close to 2900 K (4760 °F) with no apparent degradation. This design places the absorber totally within the pressurized propellant, which prevents vaporization of the absorber material and also prevents contamination of concentrator or spacecraft surfaces. Improvements are needed before it can be said that the IHPRT goals were officially met. The absorber

size, shape, and porosity all need to be optimized to improve heat transfer to the propellant to match the absorber temperature. This test provided the heat transfer data needed to perform that optimization. The Solar Thermal Propulsion concept uses focused sunlight to heat a lightweight propellant, which is expanded through a nozzle to generate thrust. This concept can significantly increase the efficiency of current orbit transfer systems. (Dr. M. Holmes, AFRL/PRSS, (661) 275-5615)

PROGRESS IN DIAMOND-LIKE CARBON CAPACITOR DEVELOPMENT: The Propulsion Directorate has been working with [K Systems Corp.](#), [Morgan Advanced Ceramics/Diamonex Division](#), and [Dearborn Electronics, Inc.](#) on a tri-service program to develop a high performance diamond-like carbon (DLC) dielectric material for pulse power capacitor applications. To date, a hold-off voltage of approximately 1200 V per 0.5 μm of DLC material has been achieved. This gives a potential energy density capability of 5 J/cc using a substrate thickness of 2 μm . The current state-of-the-art energy density is approximately 1.2 J/cc, so this represents a marked improvement. Dearborn Electronics, one of the largest DoD suppliers of military capacitor devices, has been manufacturing 1 μF DLC devices for test purposes. The University of Connecticut, [General Atomics Electronic Systems, Inc. \(ESI\)](#), and Eagle Pitcher will be testing the performance of the DLC dielectric material in the near future. The tri-services along with NASA plan a four-year extension to develop large DLC capacitor devices with both Dearborn Electronics and General Atomics/ESI. In conjunction, a Title III program will be considered to augment an Army ManTech program to ensure US supremacy in the design and manufacture of pulse power capacitors, of which DLC capacitors would play a part. (Ms. S. Fries Carr, AFRL/PRPE, (937) 255-4101)



DLC capacitor devices (> 1 μF) manufactured by Dearborn Electronics

NEW WORKSTATIONS IMPROVE INSPECTION OF SOLID ROCKET MOTORS:

The Propulsion Directorate recently completed a Small Business Innovation Research (SBIR) program with [ARACOR Corporation](http://www.aracor.com) titled “Extraction of Rocket Propellant Physical Properties via X-ray Computed Tomography (CT).” As a result of this program, the Propulsion Directorate at Edwards AFB, California, and the Ogden Air Logistics Center (OO-ALC) at Hill AFB, Utah, recently took delivery of three-dimensional imaging workstations to use in analyzing CT images of solid rocket motors. X-ray CT is a radiographic inspection method that uses a computer to reconstruct an



A computed tomography image

image from cross-sectional views through an object. The resulting image accurately represents the internal and external geometry of the object, unlike conventional X-ray techniques, in which features are superimposed onto a single plane. CT imaging is the only nondestructive method for producing quantitative three-dimensional measurements of defects and density variations in large structures, such as solid rocket motors. OO-ALC has already put the new workstation to effective use on the Minuteman Propulsion Replacement Program as well as some of their other programs, and it has proven to be very popular. This will be a valuable tool for solid rocket motor production acceptance, aging, and surveillance programs since it provides a large improvement in nondestructive evaluation capabilities. (Mr. J. Hildreth, AFRL/PRSB, (661) 275-5338)

Want more information?

- ❖ An ARACOR press release on this program is available here:
<http://www.aracor.com/pages/rocketmotor.html>
- ❖ More information on ARACOR's CT imaging is available here:
<http://www.aracor.com/pages/products/ct.html>

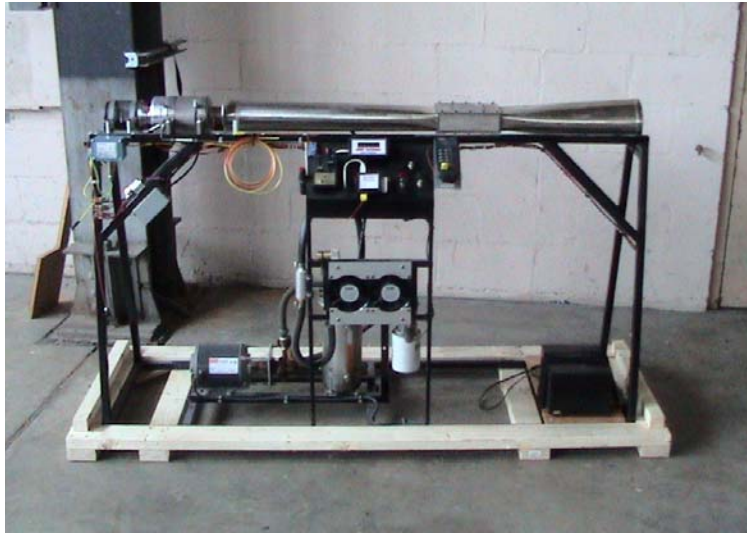
HIGH PERFORMANCE MONOPROPELLANT SUCCESSFULLY FIRED:

In a collaborative effort between the Propulsion Directorate and NASA Marshall Space Flight Center (MSFC), a successful test-firing was accomplished with an ionic liquid (IL)-based monopropellant. This monopropellant, AF-M315P, has a theoretical performance that is 70% greater than the state-of-the-art monopropellant, hydrazine. In fact, AF-M315P is the highest performing IL-based monopropellant to be fired in a thruster to date. There is



Firing of the AF-M315P monopropellant

considerable interest in finding a replacement for hydrazine, which is used in systems such as F-16 auxiliary power units. Candidate hydrazine replacements feature lower cost and lower toxicity, which benefits the environment as well as offering significant savings relative to the time and expense associated with handling hydrazine. Future plans for the AF-M315P monopropellant include determination of combustion sustainability (with an igniter), evaluation of chamber pressure effects, and assessment of combustion efficiencies and temperatures. This information will aid in the establishment of a reference base for Phase III Integrated High Payoff Rocket Propulsion Technology (IHPRT) monopropellant development. (Dr. T. Hawkins, AFRL/PRSP, (661) 275-5449)



Micro-turbine engine test rig

MICRO-TURBINE ENGINES COMING TO WRIGHT- PATTERSON AFB:

In conjunction with the Materials and Manufacturing Directorate, the Propulsion Directorate and [SWB Turbines](#) are establishing a micro-turbine engine test rig at Wright-Patterson AFB, Ohio. This rig, acquired through an AFRL/ML Small Business Innovation Research (SBIR) program, is designed to expose matrix composite materials to high temperatures in an oxidative environment by placing material

samples in the engine's exhaust. The unit consists of a SWB-4 turbojet engine with 40 lbs of static thrust that can operate continuously at 90,000 RPM. The test stand comes instrumented to monitor both the engine and exhaust temperatures and is equipped with electronic throttle control. The rig will be located in PR's Turbine Engine Fatigue Facility (TEFF), with plans to incorporate it with the Intelligent Control Facility (ICF) to conduct engine simulation and further research into engine health management. (2Lt P. Drew, AFRL/PRTS, (937) 656-5530)



Ms. Jonna Hamrick was named the Financial Management and Comptroller Individual of the Year

EXCELLENCE IN FINANCIAL MANAGEMENT

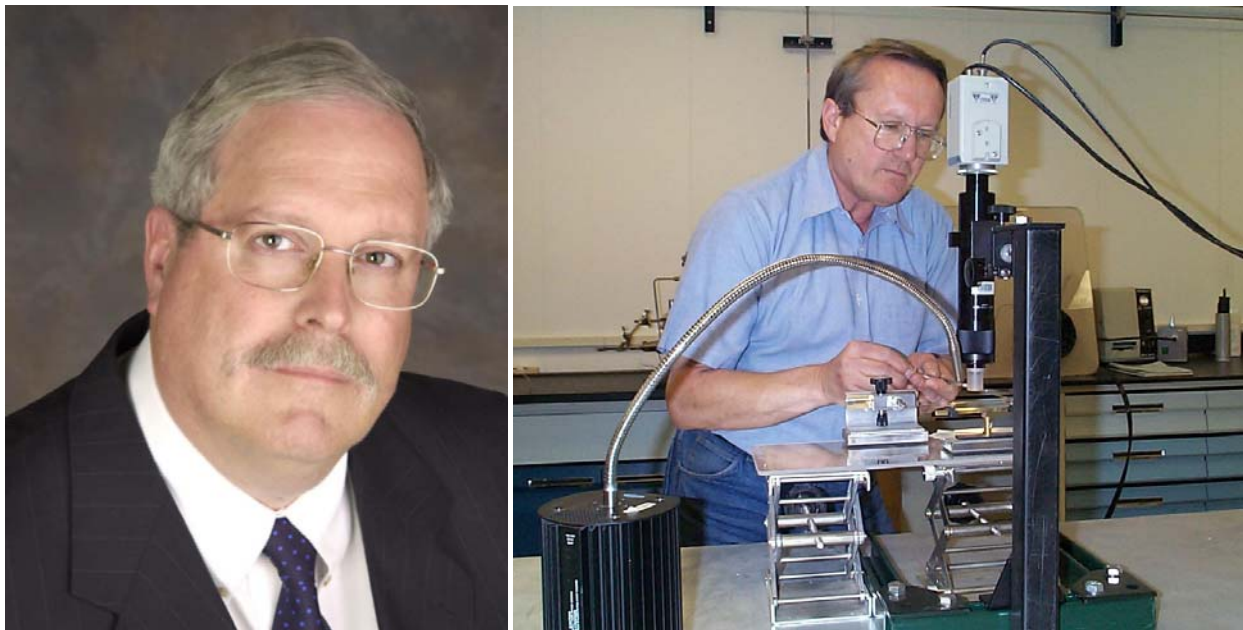
HONORED: AFRL recently announced the winners of the 2004 Financial Management (AFRL/FM) Awards, and a number of Propulsion Directorate financial management professionals were honored for their efforts. Ms. Jonna Hamrick was named the Financial Management and Comptroller Individual of the Year. In addition, a PR team was recognized for Outstanding

Contribution to Air Force Financial Transformation. The members of this team are Ms. Temeca Jones, Ms. Erin Roberts, Ms. Lisa Gallagher, and Mr. Eric Talley. The G2 team at Edwards AFB also received a Special Act Award for their outstanding work on the G2 system. The winners of this Special Act Award include Mr. David Harder, Ms. Lori Williams, Mr. Thomas Hassig, Ms. Minerva McFarland, and Mr. Eric Talley. These winners will go on to compete for awards at the Air Force Materiel Command level and, if successful, at the Air Force level. (Mr. P. Mitchell, AFRL/PRF, (937) 255-3044)

Want more information?

- ❖ A *Skywrighter* article* on the AFRL/FM Awards Ceremony is available online here: <http://www.skywrighter.com/people/2004/1210/7AFRLaward.asp>

NEW PATENT EXPLOITS MICROTUBE TECHNOLOGY: Propulsion Directorate researchers were issued [US Patent #6,818,162](#), “Method of Manufacture of Baby-Feeding Nipple,” on 16 November 2004. The inventors of this patent are Drs. Wes Hoffman and Phil Wapner of PR’s High Temperature Components group, and Dr. Alex Pechenik, formerly of AFOSR. This patent provides methods for fabricating simple, inexpensive baby bottle nipples which mimic the function of the human breast nipple. This invention offers many improvements over current technology in the area, such as: (1) delivery of fluid by means of capillary pressure, (2) relief of the slightest vacuum established during feeding, (3) integral microscopic filtering that prevents clogging, and (4) ease of cleaning and sterilization. This invention stems from PR’s extensive expertise in the area of microtubes, and it is of interest to manufacturers of infant supplies. (Dr. W. Hoffman, AFRL/PRSM, (661) 275-5768)



Dr. Wes Hoffman (L) and Dr. Phil Wapner (R) are co-inventors of a new patent for the manufacture of baby-feeding nipples

* Cooper, Mindy, “AFRL Financial Management Awards Announced,” *Skywrighter*, December 10, 2004, p. 7A.